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(56) Documents Cited
GB 2345980 A **GB 2317023 A**
US 5838870 A **US 5078516 A**

(58) Field of Search
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INT CL[7] **G02B**

(54) Abstract Title
A tapered optical waveguide formed with two substrates

(57) A method of forming a tapered optical waveguide comprising the steps:
fabricating a rib waveguide (3) on a first substrate (1)
fabricating a tapering structure (6) on a second substrate (2); and
bonding the first and second substrates (1) and (2) together so the tapering structure (6) is optically coupled to the rib waveguide (3) so as to form a tapered waveguide. Preferably the waveguides are formed by etching and bonded by a direct wafer bonding technique. Also provided is a taper optical waveguide with a v-groove for aligning an optical fibre with the waveguide.

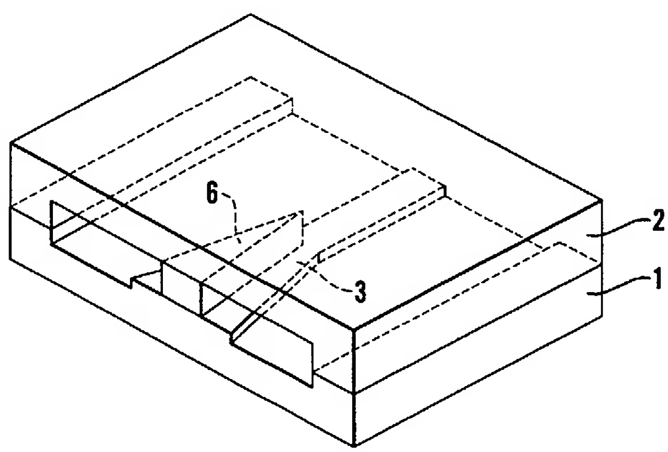

Fig.4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

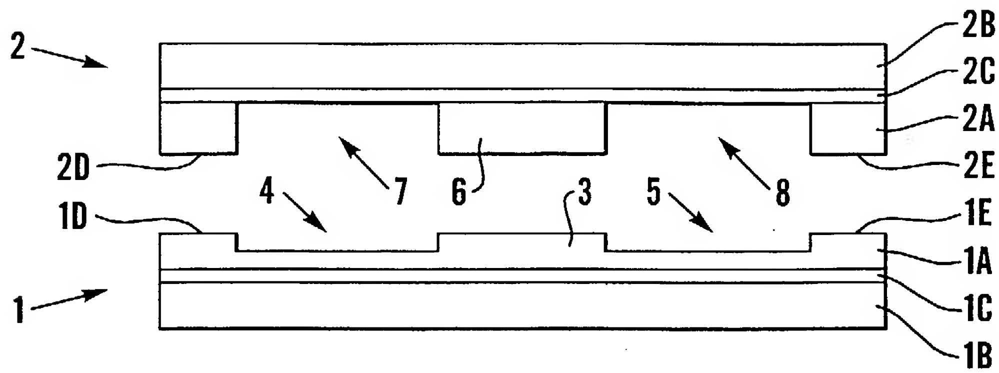

Fig. 1

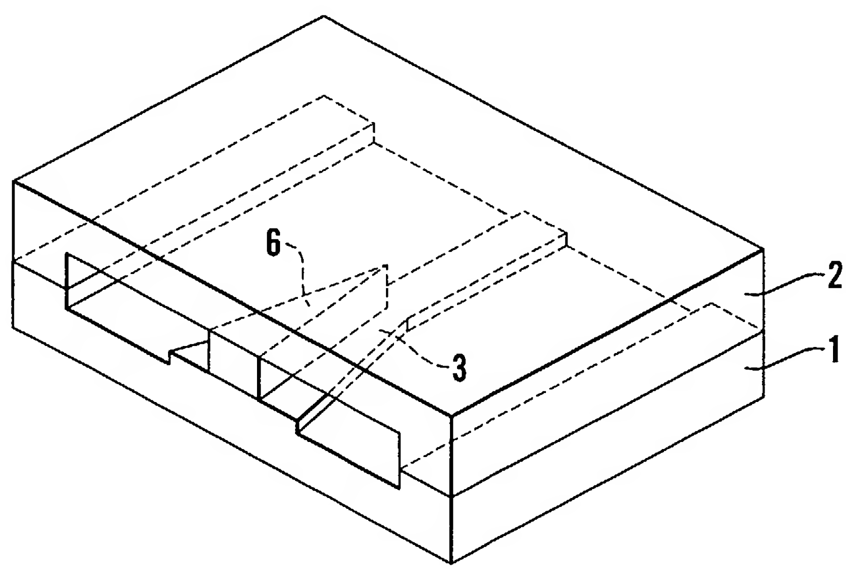

Fig.4

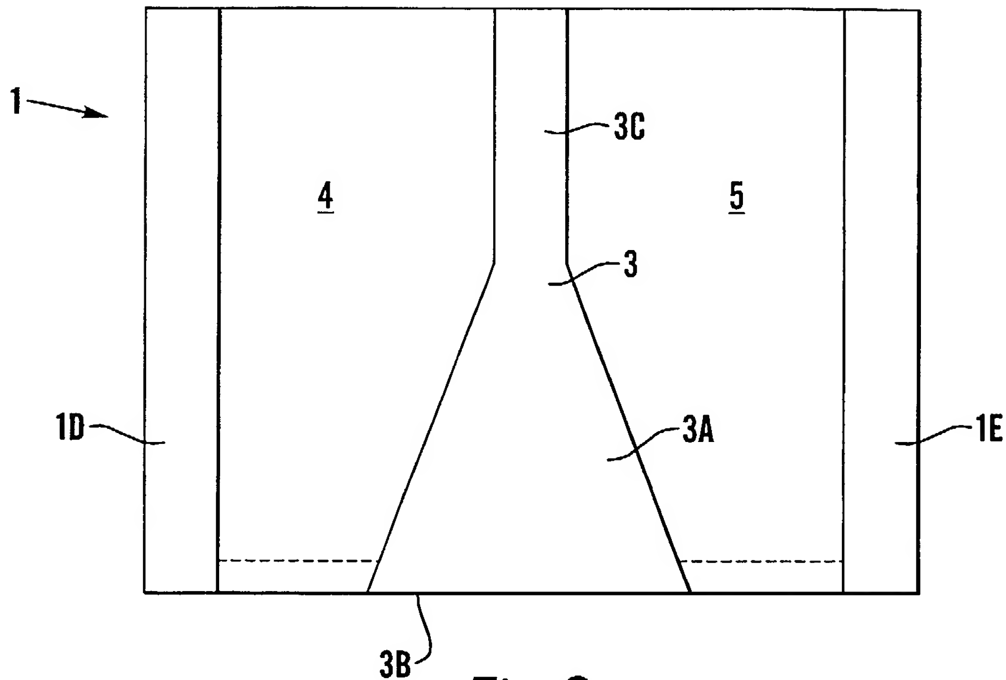

Fig.2

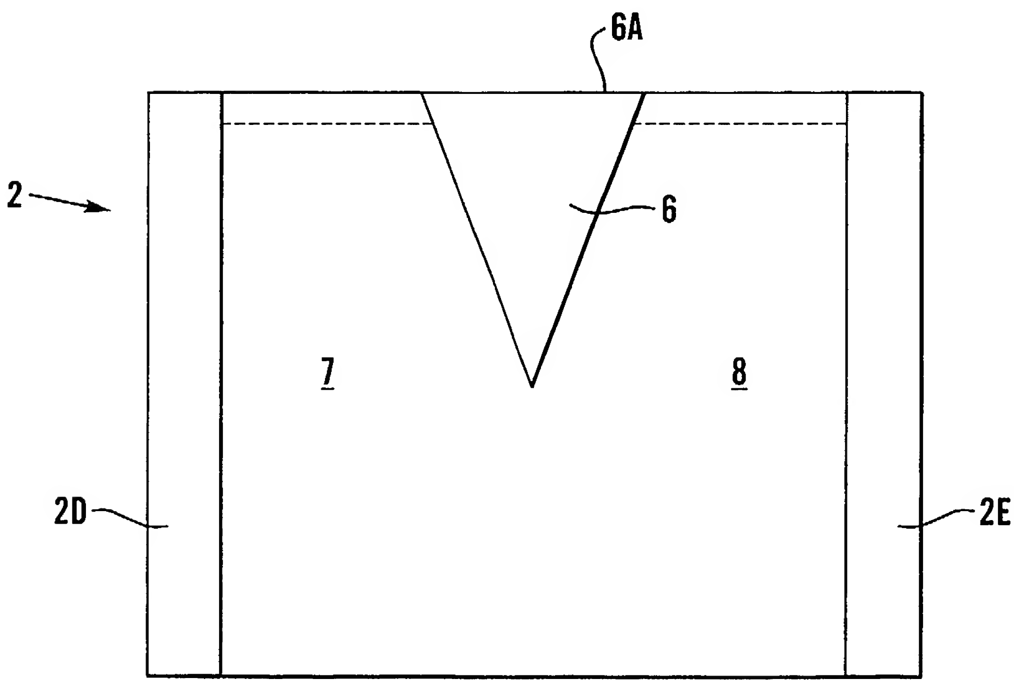

Fig.3

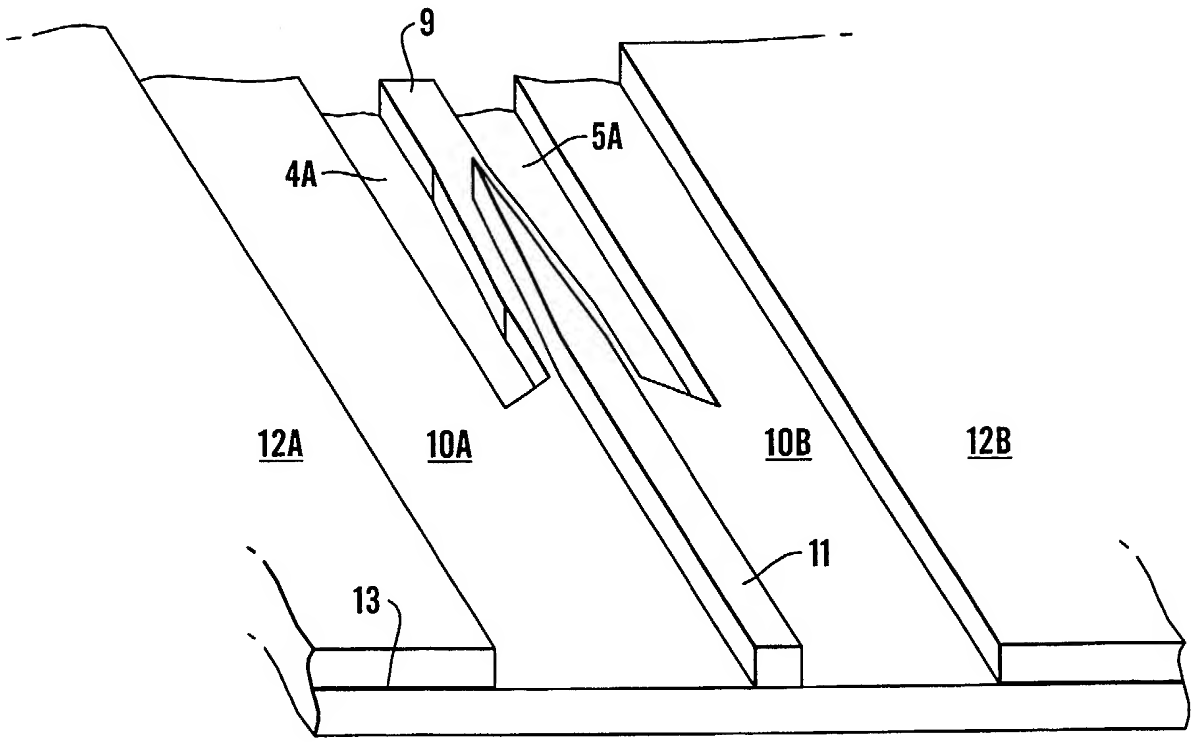

Fig.5A

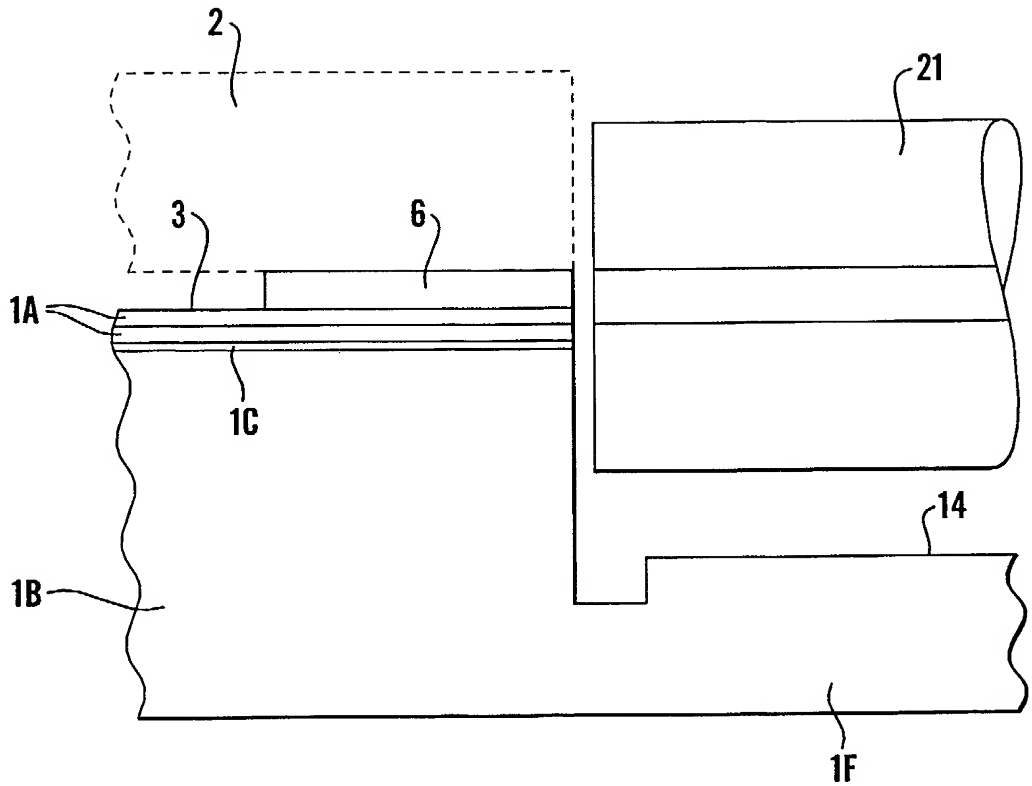

Fig.5B

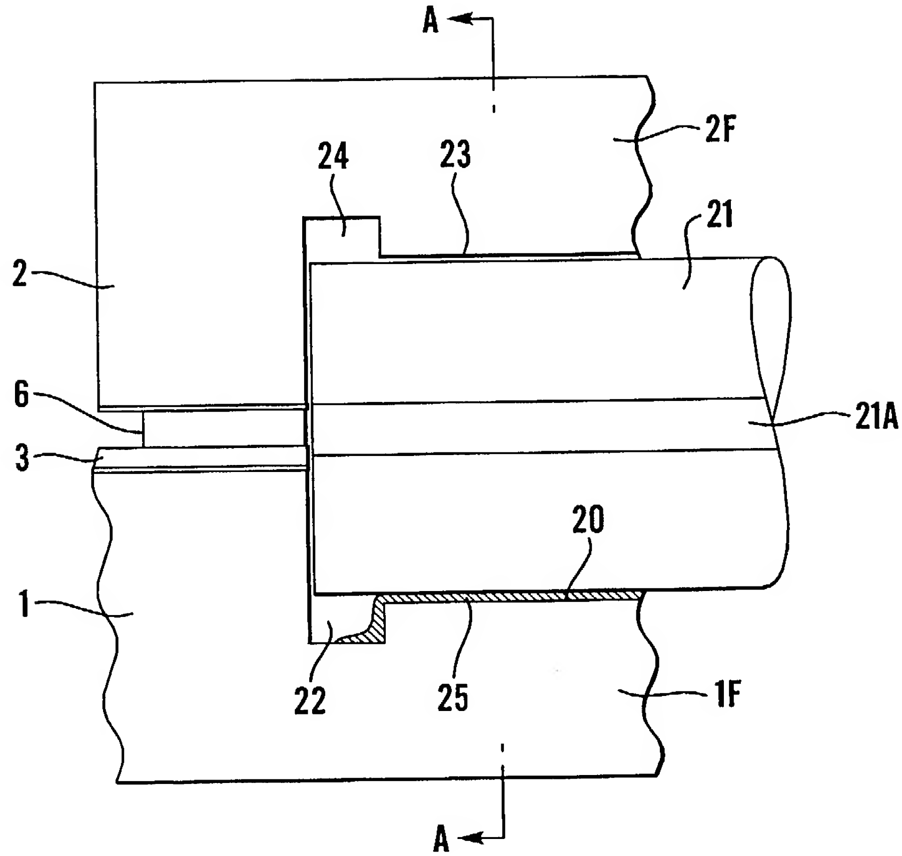

Fig.6A

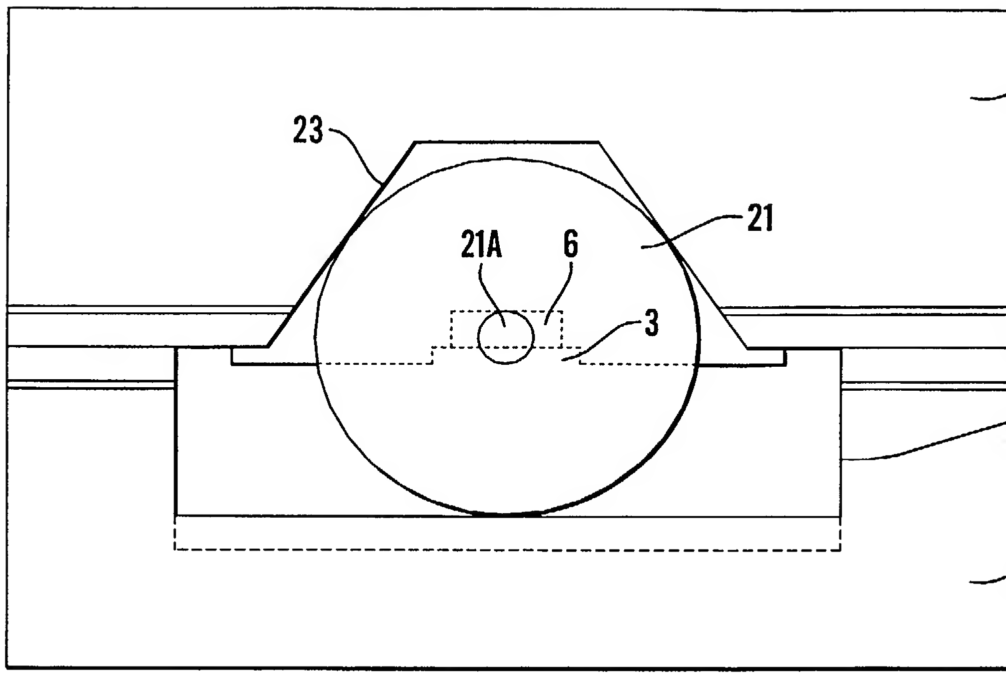

Fig.6B

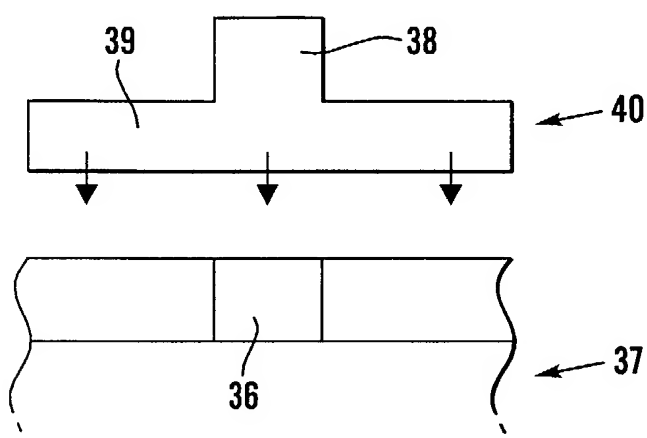

Fig.9

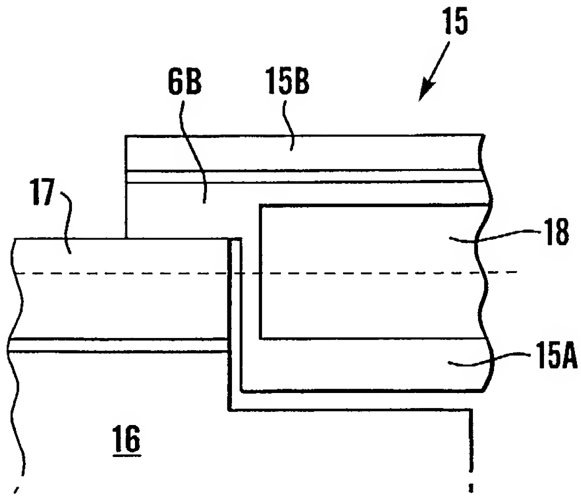

Fig.7A

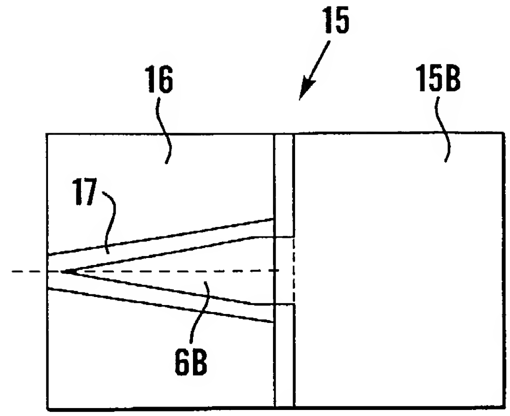

Fig.7B

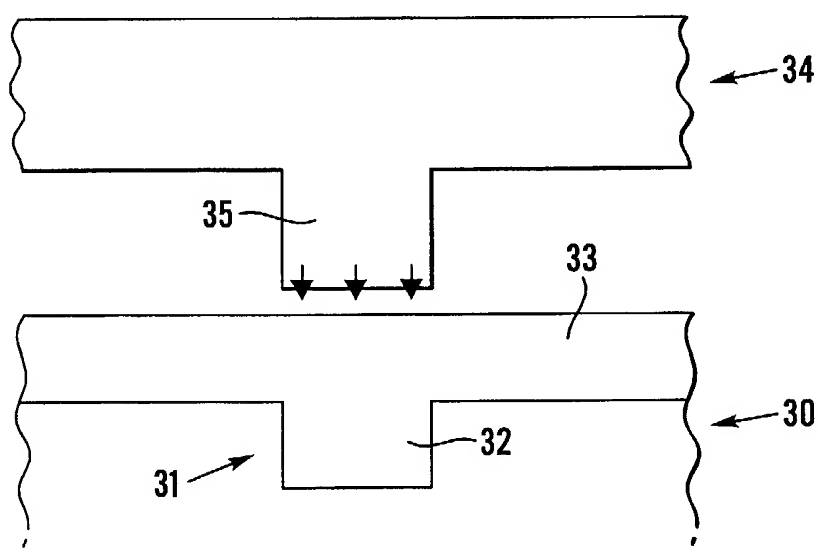

Fig.8

A TAPERED OPTICAL WAVEGUIDE

This invention relates to a tapered optical waveguide and to a method of forming the same.

Tapered optical waveguides comprising a tapered structure, e.g. a wedge-shaped structure positioned on a rib waveguide are known, e.g. as disclosed in US6108478, the disclosure of which is incorporated herein. However, due to the combined depth (in a direction perpendicular to the plane of the optical chip on which they are formed) of the tapered structure and of the rib waveguide, which may be 10 microns or more (particularly when the taper is designed to couple with an optical fibre), difficulties can be experienced in fabricating the structure to the desired accuracy.

The present invention relates to an alternative method of fabricating a tapered optical waveguide, and to products formed thereby, which seeks to avoid or overcome some of the difficulties experienced with the prior art.

According to a first aspect of the present invention, there is provided a method of forming a tapered optical waveguide comprising the steps:

fabricating a rib waveguide on a first substrate;

fabricating a tapering structure on a second substrate ; and

bonding the first and second substrates together so the tapering structure is optically coupled to the rib waveguide so as to form a tapered optical waveguide.

According to a second aspect of the invention, there is provided a method of forming a tapered optical waveguide comprising the steps:

forming a wafer comprising a waveguide layer separated from a substrate by an optical confinement layer, the waveguide layer and the substrate layer being formed of the same crystalline material but with different crystallographic orientations;

fabricating a rib waveguide in the waveguide layer and fabricating a tapering structure optically coupled with the rib waveguide to form a tapered optical waveguide; and

fabricating a V-groove in the substrate layer for receiving and locating an optical fibre in optical alignment with the tapered optical waveguide.

According to another aspect of the present invention, there is provided a tapered optical waveguide comprising a tapered structure on a rib waveguide, the rib waveguide being defined between trenches formed in a first substrate and the tapered structure being defined between trenches formed in a second substrate, the first and second substrates being bonded together so the trenches in the respective substrates together define the tapered optical waveguide.

According to a further aspect of the invention, there is provided a tapered optical waveguide formed on a chip or wafer comprising a waveguide layer separated from a substrate layer by an optical confinement layer, the waveguide layer and the substrate layer being formed of the same crystalline material but with different crystallographic orientations; a rib waveguide being formed in the waveguiding layer with a tapered structure optically coupled therewith to form a

tapered optical waveguide and a V-groove being formed on the substrate layer for receiving and locating an optical fibre in optical alignment with the tapered optical waveguide.

Preferred and optional features of the invention will be apparent from the following description and from the subsidiary claims of the specification.

The invention will now be further described, merely by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is an end view of first and second substrates prior to being bonded together in a preferred embodiment of the invention;

Figure 2 is a plan view of the first substrate shown in Figure 1;

Figure 3 is an underneath view of the second substrate shown in Figure 1;

Figure 4 is a perspective view of the substrates shown in Figures 1 to 3 when bonded together;

Figure 5A is a perspective view of a second embodiment of a tapered optical waveguide according to the invention with part of the upper substrate omitted for clarity;

Figure 5B is a cross-sectional view of a third embodiment of a tapered optical waveguide according to the invention;

Figure 6A is a cross-sectional view from one side of a fourth embodiment of a tapered optical waveguide according to the invention;

Figure 6B is a cross-sectional view taken along line A-A of Figure 6A;

Figure 7A is a cross-sectional side view of a fifth embodiment of a tapered optical waveguide according to the invention and Figure 7B is a plan view thereof;

Figure 8 is a schematic end view of a sixth embodiment of a tapered optical waveguide according to the invention; and

Figure 9 is a schematic end view of a seventh embodiment of a tapered optical waveguide according to the invention.

Figure 1 shows end views of a first substrate 1 and a second substrate 2. The substrates may comprise individual semiconductor chips or may comprise first and second semiconductor wafers if many devices are being formed together at wafer level prior to being divided into individual chips or devices.

The first chip 1 comprises a rib waveguide 3 defined between trenches 4 and 5 etched in a surface of the chip 1. The rib waveguide 3 comprises a tapering portion 3A which tapers from a wide end 3B at one edge of the chip 1 to a narrower parallel sided section 3C (as shown in Figure 3).

As shown in Figure 3, the second chip 2 comprises a tapered, wedge-shaped portion 6 defined between trenches 7 and 8 etched in a surface of the chip 2. The wedge-shaped portion tapers from a wide end 6A at one edge of the chip to a point 6B, part way across the chip 2 (where the trenches 7 and 8 meet).

The first and second chip 1, 2 are preferably silicon chips, e.g. silicon-on-insulator (SOI) chips comprising a silicon layer 1A, 2A separated from a substrate 1B, 2B (typically also of silicon) by an insulating layer 1C, 2C, e.g. of silicon dioxide.

The rib waveguide 3 and the wedge-shaped portion 6 are formed on the respective chips 1, 2 whilst these chips are separate from each other. These features can thus be fabricated independently of each other so the fabrication of one part does not affect or compromise the fabrication of the other part. In particular, the rib waveguide 3 can be etched in a known manner and the accuracy of the etch process is not prejudiced by the need to form the wedge-shaped portion from the same substrate. Instead, the wedge-shaped portion is formed separately on a second substrate and can, again, be fabricated with a high degree of accuracy using conventional etching techniques.

Once the relevant features have been fabricated in the respective substrates, the substrates are then bonded together to form a structure as shown in Figure 4. This may be achieved by a bonding technique known as direct wafer bonding (DWB). This technique generally involves preparation of the surfaces to be bonded together to make them as smooth as possible and then pressing the two surfaces together. Thermal cycling may then be used to increase the bond strength. Such bonding techniques are well known so will not be described further. Further details are also given in GB0030442.8 (Publication No.....).

Such bonding techniques allow the re-creation of atomic links, e.g. between two silicon substrates, such that the interface is no longer detectable and the two parts, in effect, become one.

In the example described above in relation to Figures 1 to 3, bonding occurs between the wedge-shaped portion 6 and the rib waveguide 3 and between planar areas 1D and 1E and planar areas 2D and 2E on the outer sides of trenches 4, 5, 7 and 8. It will be appreciated that areas 1D and 1E are automatically co-planar with the outer surface of rib waveguide 3 as these surfaces are all derived from the original surface of the chip 1. Similarly, areas 2D and 2E are automatically co-planar with the outer surface of wedge-shaped portion 6 as these are all derived from the original surface of the chip 2.

Lateral alignment of the two chips 1 and 2, i.e. in directions parallel to the planes thereof, may be effected by manual alignment of the two components or by automatic assembly machines, which typically enable an alignment accuracy of up to about 0.5 – 1.0 micron. Alternatively, alignment means may be provided to assist in aligning the two components with greater accuracy. A wide range of alignment means may be used. One example is to form a step or abutment formed on the surface of one chip by dry etching and butting a side face or step of the other chip up against this. Preferably the locations of the step and/or the side face are determined by the same lithographic mask(s) used to define the positions of the rib waveguide and/or the wedge-shaped portion 6 so they are automatically formed in known positions relative to these features. Another example is the use of matching projections and location pits formed in the areas 1D, 1E, 2D and 2E, e.g. by etching pyramidal or frusto–pyramidal projections and recesses in the respective surfaces by wet etching.

A further advantage of the device described above is that not only can the wedge-shaped portion be fabricated to a high degree of accuracy (as its fabrication is not affected by the fabrication of the rib waveguide) but, once the two substrates have been bonded together, it is protected from accidental damage as the second substrate forms a lid over the tapered optical waveguide.

This is of significant benefit as the sharpness of the narrow end of the wedge-shaped portion is important in minimising optical losses in the tapered waveguide. If the narrow end of the wedge-shaped portion is very thin it is correspondingly weak and thus vulnerable to damage. In known arrangements, the wedge-shaped portion projects from an exposed surface of the device and is easily damaged during handling of the device whereas in the arrangement described above, it is protected by the lid formed by the second substrate being mounted over the first substrate.

Another advantage of the arrangement described above is that the wide ends of the wedge-shaped portion and rib waveguide are less vulnerable to damage when they are polished. Firstly, as the end of the wedge-shaped portion is sandwiched between the rib waveguide of the first substrate and a slab region of the second substrate, two sides of its wide end face and all four corners thereof are less vulnerable to chipping during the polishing process. Secondly, in a modified embodiment, the ends of the channels formed on either side of the tapered waveguide structure by the pairs of trenches 4,5 and 7,8, may be blocked, or at least partially occluded, by barriers 14 formed at the ends thereof (as shown by dashed lines in Figures 2 and 3). The barriers 14 comprise thin walls of silicon left on the first and/or second substrates 1, 2 during the etching of the other features. The barriers 14 thus provide additional protection to the side edges of the wide ends of the wedge-shaped portion and rib waveguide during polishing of the end faces and also serve to prevent debris generated during polishing from falling into the channels.

Although Figures 1-3 show only a single tapered optical waveguide, it will be appreciated that a plurality of such waveguides may be formed at spaced intervals along an edge of a device such as that shown in the Figures.

Figure 5 shows a second embodiment of a tapered optical waveguide which may be formed by the method described above. In this case, the trenches 4A and 5A defining a rib waveguide 9 therebetween stop short of the edge of the device. The rib waveguide 9 and the flat areas 10A and 10B on either side thereof are formed on a first chip. A tapered structure 11 and flat areas 12A and 12B are formed on a second chip (the remainder of which is omitted from Figure 5 for clarity). The two chips are then bonded together about a plane which includes the area 10A and 10B and the line 13 shown at the edge of the device. In this embodiment, it may be desirable to provide a thin oxide layer between the tapered structure 11 and the rib waveguide 9, i.e. on the bond plane, as discussed further below.

As indicated above, the tapered waveguide is particularly useful in providing an optical coupling between an optical fibre and a rib waveguide. An optical fibre may be aligned with the wide end of the tapered waveguide by locating the fibre in a V-groove formed in an extended portion of the first chip 1. It is known to align an optical fibre with a tapered waveguide in this manner as described in US6108478 referred to above. Figure 5B shows a cross sectional view of a device which, with the parts shown in dashed lines, corresponds to the arrangement shown in Figure 1 but with a V-groove 14 formed in an extended portion 1F of the first chip 1. An optical fibre 21 is located in the V-groove 14 in optical alignment with the tapered waveguide formed by the rib waveguide 3 and the wedge-shaped portion 6. However, the formation of V-grooves 14 in a first chip 1 and the tapered structure 6 on a second chip 2, in the manner described above, provides significant advantages. One method of forming a wedge-shaped portion on a rib waveguide involves forming the wedge-shaped portion on the top of the rib waveguide by epitaxial growth. However, for accurate fabrication by this method it is desirable to form such devices at 45 degrees to the major flat of a conventional SOI wafer. This is incompatible with

the wet etch process used to form the V-grooves as this is dependent on the crystal orientation and thus forms the V-grooves at 90 degrees to the major flat. By forming the wedge-shaped portion and the V-grooves on separate chips, each can be formed in its preferred orientation on the respective chip. Thus, fabrication of a tapered optical waveguide in the manner described above permits the crystal orientation of the two chips 1,2, and hence of the components formed therein, to be different to each other.

Figure 6A shows a cross-sectional side view of a further extension of the embodiment described above. The first chip 1 has an extension 1F in which a groove 20 is formed and a fibre 21 supported thereon. In this case, the groove 20 has a rectangular cross-section and does not serve to locate the fibre 21 laterally, i.e. in a direction parallel to the plane of the chip and perpendicular to the optical axis of the fibre. A deep etched portion 22 is formed at the end of the groove 20 to receive any excess material 25 which is provided in the groove 20 to compensate for variations in the fibre diameter. The material 25 is typically a malleable material such as gold. The deep etched portion 22 also removes any rounded corners left at the end of the groove 20. In this embodiment, the second chip 2 also has an extension 2F in which a V-groove 23 is formed. A deep etched portion 24 is also formed at the end of the V-groove 23 to remove the inclined end face which is otherwise present at the end of the V-groove (as described in WO-A-99/57591).

As shown in Figure 6B, the V-groove 23 need not be etched to the depth at which the two sides thereof meet but need only be etched to a depth sufficient to accommodate the fibre 21 (so the V-groove 23 has a flat base). The V-groove 23 serves to locate the fibre 21 laterally. As the wedge-shaped portion 6 is formed on the second chip 2, it is automatically aligned with the V-groove 23, and hence the fibre 21, in the lateral direction as the position of the two

features can be defined in the same lithographic step. The vertical alignment (i.e. in a direction perpendicular to the plane of the chip) between the wedge-shaped portion 6 and the fibre 21 is also accurately determined by the depth of the V-groove 23. If the wedge-shaped portion 6 is fabricated by an etching process, e.g. a dry etch (rather than by epitaxial growth), it can be fabricated accurately on the same chip as the V-groove 23.

In yet another embodiment shown in Figures 7A and 7B, the second structure on which a wedge-shaped portion 6B is provided may form part of a fibre block 15 mounted adjacent a vertical edge of the first substrate 16. A rib waveguide 17 is provided on the first substrate 16. The rib waveguide 17 terminates at a vertical face which may be the edge of the first substrate 16 or a vertical face formed within a recess in the first substrate (as shown in Figure 7A). Typically, the fibre block 15 comprises a base 15A and a lid 15B, each having V-grooves formed therein and between which the ends of one or more optical fibres 18 are held. Such fibre blocks are typically used to locate the end of a fibre ribbon comprising eight or more fibres, in alignment with corresponding waveguides on a substrate. In the arrangement shown in Figure 7A, the lid 15B of the fibre block 15 extends over the upper surface of the rib waveguide 17 and is provided with a wedge-shaped portion 6B for forming a tapered optical waveguide with the rib waveguide 17 as shown in Figures 7A and 7B. The underside of the wedge-shaped portion 6B is bonded to the upper surface of the rib waveguide 17 as described above.

In this embodiment, the wedge-shaped portion 6B not only forms part of a tapered optical waveguide but also helps locate the fibre block 15 relative to the first substrate 16. In addition, the wedge-shaped portion 6B is combined with components used to hold and locate the end of an optical fibre relative to the waveguide.

The lid 15B of the fibre block 15 may comprise a silicon-on-insulator (SOI) chip in which the wedge-shaped portion 6B and V-grooves used to locate the fibre 18 are formed. Such an arrangement may be formed by dry etching the wedge-shaped portion 6B and wet-etching the V-grooves (as described above in relation to Figures 6A and 6B). Alternatively, the wedge-shaped portion may be formed by epitaxial growth on the SOI wafer. However, as indicated above, accurate fabrication of the wedge-shaped portion by this method requires the silicon crystal to be in an orientation incompatible with the orientation of the V-grooves. One way of overcoming this is to use an SOI chip in which the upper silicon layer is in a different orientation to the silicon substrate. Such a wafer can be formed by first forming a silicon substrate with a oxide layer thereon and then bonding a further silicon layer to the oxide layer at the required orientation with the silicon substrate. The wedge-shaped portion 6B can thus be accurately formed in the said further silicon layer whilst the V-grooves (whose orientation is determined by the crystallographic orientation of the silicon substrate) can be formed in the desired orientation relative to the wedge-shaped portion.

Whilst the above embodiments comprise a silicon wedge-shaped portion bonded directly to a silicon rib waveguide, it should be noted that in some circumstances it may be desirable for a thin layer, e.g. of oxide or nitride, to be provided therebetween. This layer should be as thin as possible so as not to affect the optical coupling between the wedge-shaped portion and the rib waveguide and would typically have a thickness of around 0.05 microns. Also, other materials may be used for the wedge-shaped portion and/or the rib waveguide. If these components are formed of dissimilar materials, the provision of a thin oxide or nitride layer therebetween can help in bonding the components together.

The above description refers to a wedge-shaped portion being bonded to the upper surface of a rib waveguide, as shown in Figure 4. A rib waveguide comprises a slab region from which the rib projects, the slab region being of greater width than the rib. A tapered optical waveguide can also be formed by providing a wedge-shaped portion optically coupled with the underside of the slab region of such a rib waveguide, i.e. on the opposite side of the waveguide to the upper surface of the rib.

Such an arrangement may also be fabricated by bonding two substrates together as shown in Figure 8, the first substrate 30 comprising a rib waveguide 31 in which the rib 32 projects from the slab portion 33 into the substrate rather than outwards from a surface thereof and the second substrate 34 comprising a wedge-shaped portion 35 which is bonded to the slab portion.

Figure 9 shows a further arrangement in which a wedge-shaped portion 36 is formed on but buried within a first substrate 37 and a rib waveguide comprising a rib 38 and slab portion 39 is formed on a second substrate 40 which is bonded to the first substrate 37 so that the wedge-shaped portion 36 is optically coupled to the slab portion 39.

The above embodiments describe the rib waveguide and wedge-shaped portion being fabricated prior to bonding the first and second substrates together. However, in some circumstances, it may be appropriate to bond the two substrates together prior to the fabrication of the rib waveguide in the first substrate and/or prior to fabrication of the wedge-shaped portion in the second substrate.

In a further embodiment of the invention shown in figure 5B (without the part shown in dashed lines), a device comprising both a wedge-shaped portion 6 and

V-grooves 14 may be fabricated from a wafer 1 which comprises a silicon waveguide layer 1A and a silicon substrate 1B separated by an insulating layer or optical confinement layer 1C, with the two layers of silicon 1A, 1B in different crystallographic orientations. As described above, such an SOI wafer can be fabricated by forming a silicon substrate 1B with an oxide layer 1C thereon and bonding a further silicon layer 1A to the oxide layer 1C in the desired orientation relative to the silicon substrate 1B. A rib waveguide 3 can then be formed in the silicon layer 1A and a wedge-shaped portion 6 fabricated thereon by epitaxial growth. The V-grooves 14 are formed in the silicon substrate 1B. Thus, in this embodiment, the bonded interface is between the silicon layer 1A and the optical confinement layer 1C (or may be between the optical confinement layer and the silicon substrate 1B) rather than between the wedge-shaped portion 6 and the rib waveguide 3.

CLAIMS

1. A method of forming a tapered optical waveguide comprising the steps:

fabricating a rib waveguide on a first substrate;

fabricating a tapering structure on a second substrate ; and

bonding the first and second substrates together so the tapering structure is optically coupled to the rib waveguide so as to form a tapered optical waveguide.

2. A method as claimed in claim 1 in which the rib waveguide and/or the tapering structure are fabricated by an etching process.

3. A method as claimed in claim 1 or 2 in which the first and second substrates are bonded to each other by a direct wafer bonding technique.

4. A method as claimed in claim 1, 2 or 3 in which the rib waveguide and the tapering structure are formed of similar material, preferably silicon.

5. A method as claimed in any preceding claim in which the rib waveguide and the tapering structure are separated by a relatively thin layer, preferably an oxide or a nitride of the material from which one or both are formed.

6. A method as claimed in any preceding claim in which the rib waveguide comprises a slab region and a rib projecting therefrom, the tapering

structure being bonded to a surface of the rib remote from the slab region.

7. A method as claimed in any preceding claim in which the tapering structure comprises a wedge-shaped portion.

8. A method as claimed in any preceding claim in which the first substrate comprises a first chip and the second substrate comprises a second chip, the rib waveguide being fabricated on a surface of the first chip and the tapering structure being fabricated on a surface of the second chip, the second chip then being inverted relative to the first chip prior to the two chips being bonded together.

9. A method as claimed in any preceding claim in which the second substrate comprises a V-groove for locating an optical fibre in alignment with the tapering structure, the positions of the V-groove and tapering structure being defined by the same lithographic step.

10. A method as claimed in any preceding claim in which the second substrate comprises part of a fibre block used to hold an optical fibre in alignment with the rib waveguide.

11. A method as claimed in any preceding claim in which the first and second substrates are bonded together prior to the fabrication of the rib waveguide on the first substrate and/or prior to the fabrication of the tapering structure on the second substrate.

12. A method of forming a tapered optical waveguide comprising the steps:

forming a wafer comprising a waveguide layer separated from a substrate by an optical confinement layer, the waveguide layer and the substrate layer being formed of the same crystalline material but with different crystallographic orientations;

fabricating a rib waveguide in the waveguide layer and fabricating a tapering structure optically coupled with the rib waveguide to form a tapered optical waveguide; and

fabricating a V-groove in the substrate layer for receiving and locating an optical fibre in optical alignment with the tapered optical waveguide.

13. A method of forming a tapered optical waveguide substantially as hereinbefore described with reference to one or more of the accompanying drawings.

14. A tapered optical waveguide comprising a tapered structure on a rib waveguide, the rib waveguide being defined between trenches formed in a first substrate and the tapered structure being defined between trenches formed in a second substrate, the first and second substrates being bonded together so the trenches in the respective substrates together define the tapered optical waveguide.

15. A waveguide as claimed in claim 14, in which the rib waveguide comprises a slab region and a rib projecting therefrom, the tapered structure being optically coupled to a surface of the rib remote from the slab region.

16. A waveguide as claimed in claim 14 or 15 in which the tapering structure comprises a wedge-shaped portion.

17. A waveguide as claimed in claim 14, 15 or 16 in which the first and second substrates are substantially planar and the combined dimensions of the rib waveguide and the tapering structure in a direction perpendicular to planes of the first and second substrate is 10 microns or more.

18. A waveguide as claimed in any of claims 14 to 17 in which ends of the said channels adjacent a wide end of the tapered waveguide are at least partially occluded.

19. A waveguide as claimed in any of claims 14 to 18 in which the first and second substrates are substantially planar comprising alignment means for aligning the second substrate relative to the first substrate in a direction parallel to the planes thereof.

20. A waveguide as claimed in any of claims 14 to 19, in which an external edge of the first substrate is aligned with an external edge of the second substrate in which the trenches formed in the first substrate stop short of the said external edge thereof.

21. A waveguide as claimed in any of claims 14 to 20 in which the second substrate comprises a V-groove for locating an optical fibre in alignment with the tapered structure.

22. A waveguide as claimed in any of claims 14 to 21 in which the second substrate comprises part of a fibre block used to hold the end of an optical fibre in alignment with the rib waveguide.

23. A waveguide as claimed in any of claims 14 to 21 in which the crystalline structure of the first and second substrates are in different alignments.

24. A waveguide as claimed in any of claims 14 to 23 in which the rib waveguide and the tapered structure are formed of silicon.

25. A waveguide as claimed in claim 24 in which at least one of the first and second substrates comprises a silicon-on-insulator wafer or chip.

26. A tapered optical waveguide formed on a chip or wafer comprising a waveguide layer separated from a substrate layer by an optical confinement layer, the waveguide layer and the substrate layer being formed of the same crystalline material but with different crystallographic orientations; a rib waveguide being formed in the waveguiding layer with a tapered structure optically coupled therewith to form a tapered optical waveguide and a V-groove being formed on the substrate layer for receiving and locating an optical fibre in optical alignment with the tapered optical waveguide.

27. A tapered optical waveguide substantially as hereinbefore described with reference to and/or as shown in one or more of the accompanying drawings.

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 0106742.0 **Examiner:** Richard Nicholls
Claims searched: 12-13 and 26-27 **Date of search:** 31 August 2001

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G2J (JGDA, JGDBF)

Int Cl (Ed.7): G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2345980 A	(Samsung) see especially figure 1	12 and 26 at least
Y	GB 2317023 A	(Bookham) see especially figure 1	12 and 26 at least
Y	US 5838870 A	(United States) see especially figure 3	12 and 26 at least
Y	US 5078516 A	(Bell) see especially figure 5	12 and 26 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Application No:	GB 0106742.0	**Examiner:**	Richard Nicholls
Claims searched:	1-11 and 14-25	**Date of search:**	27 June 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G2J (JGDA)

Int Cl (Ed.7): G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2345980 A (Samsung) see especially figure 1	
A	GB 2317023 A (Bookham) see especially figure 1	
A	US 5078516 A (Bell) see especially figure 5	

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